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HIGH VOLTAGE PLASMA SHEATH ANALYSIS
RELATED TO TSS-1

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Introduction

On the first mission of the Tethered Satellite System (TSS-1), a 1.8m diameter spherical satellite will be deployed a distance of 20 km above the space shuttle Orbiter on an insulated conducting tether. The satellite will be held at electric potentials up to 5000 volts positive with respect to the ambient plasma. Due to the passage of the conducting tether through the earth's magnetic field, an emf will be created, driving electrons down the tether to the orbiter, out through an electron gun into the ionosphere and back into the positive-biased satellite. The main problem addressed herein is the current-voltage characteristics of the ionospheric interaction with the satellite.

Instrumentation on the satellite will be capable of measuring charged particle flow to the surface at several locations, but these detectors have a limited range of acceptance angle. The second problem addressed herein is the angle of incidence the incoming electrons will have relative to the local normal. This will be important in order to predict the magnitude of the detectable current at each detector location so the detector gain can be pre-set to the correct range.

The Mathematical Model

In the ionosphere at the altitude of the planned orbit, the average thermal velocity of electrons 1.9×10^5 m/s, the average thermal velocity of the ions is 1.1×10^3 m/s and the velocity of the satellite is 8×10^3 m/s. Furthermore, the electrons spiral about the earth's magnetic field lines with a radius of 3 cm, while the ions spiral with a radius of 5m.

In the present calculation, it is assumed that there will be a sheath region around the satellite devold of ions due to the high positive potential and that electrons approach this sheath along the magnetic field lines neglecting their initial velocity due to the ambient spirals. The governing equations in this sheath are taken to be (1) the Taylor-Vlasov equations which relate the components of the electron

velocity to the local electric potential, (2) the continuity equation for electrons which relates their velocity components to the electron density and, (3) the Poisson equation which relates the electron density to the electric potential. The boundary conditions at the outer edge of the sheath are that the electron velocity is equal to the ambient electron drift velocity, the electron density is the ambient value, and the electron electric potential energy is equal to the ion kinetic energy relative to the satellite. The problem is solved in the steady state so the electron current entering the sheath is equal to the current collected by the satellite.

The Solution

Finite difference equations have been written for equations (1)-(3). Equation (1) is solved numerically by applying Newton linearization and an iterative procedure. Equation (2) is solved by a direct stepwise numerical calculation. Equation (3) is solved by the successive over-relaxation method using Chebyshev acceleration. The computer program begins by using a guessed potential distribution and solving Eq. (1) to obtain the electron velocity components and from Eq. (2) the electron density. From the radial electron velocity and electron density at the satellite surface, the current to the satellite is calculated and compared to the incoming ambient current to the sheath. The sheath radius is then adjusted to make these currents equal. Using this new sheath radius and the electron density, a new potential distribution is obtained from Eq. (3). Using this new potential, the above process is repeated until potential, electron density, and electron velocity spacial distributions have converged. Then the angles of incidence of the current to the detector locations can be obtained from the electron velocity components at the satellite surface.

Status

As of this writing, the subroutines solving Eqs. (1)-(3) have been written and tested. The assembly of the overall program is underway.

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